CROW INDIAN TRIBE

Resources Report

GEOLOGY AND MINERALS

GEOLOGY AND MINERALS

Structure and Stratigraphy

The Crow Reservation lies within the unglaciated portion of the Missouri Plateau, a subdivision of the Great Plains physiographic province. The Missouri Plateau on the Crow Reservation is described as a mature landscape consisting of flat to rolling plains dissected by rivers with scattered isolated mountains (Perry 1962). The mountain ranges on the Crow Reservation include the Bighorn Mountains and the Pryor Mountains to the west, and the Wolf/Rosebud Mountains on the east.

The Bighorn Mountains are a major structural arch that extends southward from the Bighorn Reservoir and rise from 3,560 feet at the reservoir to a maximum elevation of 9,257 feet above sea level near the Wyoming-Montana border. The mountains contain an elevated core of Precambrian crystalline rocks with remnants of nearly flat-lying lower Paleozoic rocks on top and upturned Paleozoic and Mesozoic rocks around the margins.

The Big Horn Range is divisible into three units. The northern unit is located on the reservation and extends northward from near the Montana-Wyoming border to the vicinity of the Bighorn River. This segment of the Big Horn Range is about 10-miles wide. The surface on top has a gentle northerly slope, with monoclinal folding of Paleozoic and Mesozoic strata with a westward dip of approximately 70^0 marking the western flank of the range. To the south, this monocline steepens and transitions along strike into an eastward-dipping thrust fault.

The terrain varies from steep, narrow drainage canyons, to steep-walled glacial cirque basins and windswept alpine meadows at timberline. The eastern flanks are characterized by numerous hogbacks of younger strata that dip abruptly beneath the surface along with paired anticline/syncline structures paralleling the mountain front.

The Bighorn Canyon is located in the Garvin Basin, a structural trough that separates the Bighorn Mountains from the Pryor Mountains to the north. The Pryor Mountains have been referred to as a northern extension of the Big Horn Range. However, Blackstone (1940) reported that the Pryor Mountain uplift was a separate orogenic unit. Topographically, the Pryor Mountains are moderately dissected block faulted mountains with gentle slopes and flat rolling plateaus of Madison limestone to the west and steep scarp slopes to the east. The range rises to an elevation of 8,776 feet above sea level. Structurally the Pryor Mountains are a series of moderate to steeply dipping reverse faults that bound the east front of the mountains and bring Precambrian crystalline rocks into fault contact with deformed and locally overturned Paleozoic and Mesozoic rocks. Blackstone (1975) found that the Pryor Mountains consisted of five uplifted crustal blocks: West Pryor Mountain, Northeast Pryor block, Red Pryor Mountain, East Pryor Mountain, and the Shively Hill Dome. The blocks are bound by deep-seated basement faults, symmetric faulted folds, or unfaulted asymmetric folds. Sinkholes filled with younger formations and caves are common features of the Pryor Mountains.

The Pryor Mountain uplift is divided into northern and southern segments by a fault zone that roughly parallels the upper Sage Creek drainage. The Sage Creek fault zone (Blackstone 1940) is the eastern extension of the Nye-Bowler Lineament. The Nye-Bowler Lineament is a continuous zone of structural disturbance extending for a distance of at least 115 miles from

Livingston, Montana to the Pryor Mountains. Across the northern part of the Big Horn Basin, the lineament is featured by numerous northeast-ward-trending en-echelon faults.

The Rosebud Mountains, in the southeast corner of the reservation, rise abruptly to an elevation greater than 5,000 feet. A narrow divide that separates the Davis Creek and Rosebud Creek drainage's, separates the Wolf Mountains from the Rosebud Mountains to the north. These mountains are highly dissected with numerous outcroppings of the Wasatch Formation and Fort Union Formation coal deposits. These mountains also form a drainage divide between the Little Bighorn River and the Tongue River systems.

The Powder River Basin occupies approximately 32,000 square miles in northeastern Wyoming and southeastern Montana. The Crow Reservation is located on the northwestern flank of the Montana portion of the basin (Wolf/Rosebud Mountains). It is the largest intermontane basin in the Central Rocky Mountain region. The basin is bounded by the Black Hills on the east, the Bighorn Mountains on the west, and the Laramie and Hartville Uplifts on the south. The basin merges into the Montana Plains to the north and is separated from the Williston Basin by the Miles City Arch and Cedar Creek Anticline.

The Powder River Basin contains a maximum thickness of approximately 16,000 feet of sedimentary rocks, ranging in age from middle Cambrian to Eocene. The basin plunges into Wyoming with the deepest part located near the southern end of the Bighorn Mountains. The basin is the least deformed of the Rocky Mountain basins. The basin has an asymmetry with the steeper limb adjacent to the mountain front on the west. At the southern end of the basin, there is approximately 30,000 feet of relief in the basement rocks between the Big Horn uplift and the basement rocks of the basin. In Montana, the structural relief is approximately 2,500 feet with the deepest portion at the Wyoming border.

During the Paleozoic and Mesozoic eras, until late Cretaceous time, the Powder River Basin was part of a stable marine shelf between the Transcontinental Arch (Siouxia Uplift) to the east and southeast, and the Cordilleran geosyncline to the west. Sedimentation was controlled by regional tectonics so that variations in thickness and lithology of the rock units are continuous with those of the Paleozoic and Mesozoic rocks in the surrounding uplifts. Late Cretaceous sediments show marked effects of local tectonics such as the Wolf and Rosebud Mountains.

The Wasatch Formation and the Fort Union Formation of Tertiary age cover the central and northern parts of the basin. It is these formations that contain the economic coal beds in the Montana portion of the Powder River Basin and the Crow Reservation. Older Paleozoic strata are found in the foothills of the surrounding uplifts.

The geologic formations exposed at the surface on the Crow Reservation range from Precambrian granitic gneiss and schist rocks as basement units in the Big Horn and Pryor mountains, to the younger Eocene age Wasatch Formation on the eastern flank of the reservation. With exception of small structural fluctuations, the beds gently dip easterly. In general, erosion has exposed each geologic formation at or near the surface in a series of stacked inclined formations progressing from older beds on the west to younger beds on east side of the reservation. *Tables 9A and 9B* present a general geologic section of the bedrock units found on the reservation.

Generalized Geologic Section of the Crow Reservation

References: Vuke et al. 2000(a); Vuke et al. 2000(b); BIA 1973

System	Series	Formation	Thickness (feet)	Lithologic Character	Water-Bearing Properties	Minerals	Paleontological
QUATERNARY	Holocene	Alluvium	<35	Gravel, sand, silt, and clay along active channels of rivers, streams, and tributaries.	Recharge principally by infiltrating flood water, by precipitation, and by underflow from both irrigated terraces and tributary stream valleys. Locally yields of 100 gpm can be developed from wells. 50-450gpm fair to good quality	Sand and gravel	
	Holocene and Pleistocene	Landslide Deposit	100 - 150	Rock and soil that moved downslope in discrete units through mass-wasting processes that resulted in irregular or hummocky surfaces.	Where deposits are recharged by infiltrating irrigation water, domestic and stock supplies can be obtained readily from the gravel; but where they are recharged solely by precipitation, water can be obtained only near the middle of the more extensive remnants and from small springs issuing from the base of the deposits.		
	Holocene and Pleistocene	Alluvial Fan Deposit	<50	Gravel, sand, and silt, crudely stratified, deposited at mouth of ephemeral streams at base of uplands.	Recharged principally by canal leakage, infiltrating irrigation water, and influent seepage from streams. Water table generally shallow and drainage problems common, particularly near the edges of the fans. Locally, yields of 100 gpm can be developed from wells.	Sand and gravel	
	Holocene and Pleistocene	Gravelly Sheetwash Alluvium and Colluvium	<82	Gravel, sand, silt, and clay, derived from higher level alluvial terrace deposits and to a lesser extent from bedrock sandstone and shale.	Where deposits are recharged by infiltrating irrigation water, domestic and stock supplies can be obtained readily from the gravel; but where they are recharged solely by precipitation, water can be obtained only near the middle of the more extensive remnants and from small springs issuing from the base of the deposits. <50gpm, fair to good quality	Sand and gravel	
	Pleistocene	Alluvial Terrace Deposits		Gravel, sand, silt, and clay underlying alluvial terrace surfaces adjacent to and higher in elevation than modern streams and rivers. At least eight, distinct terrace levels are recognized along Bighorn River and Little Bighorn River, ranging from 10 to 560 ft above the rivers.	Where deposits are recharged by infiltrating irrigation water, domestic and stock supplies can be obtained readily from the gravel; but where they are recharged solely by precipitation, water can be obtained only near the middle of the more extensive remnants and from small springs issuing from the base of the deposits.	Sand and gravel	
	Holocene, Pleistocene and Pliocene	Clinker	<130	Red, pink, gray, orange, black, and yellow resistant, thermally metamorphosed shale, siltstone, and sandstone of the Lance, Fort Union, and Wasatch formations.	Fairly permeable and are considered important local aquifers and spring development with good quality water.	Road material	

Generalized Geologic Section of the Crow Reservation

References: Vuke et al. 2000(a); Vuke et al. 2000(b); BIA 1973

System	Series	Formation	Thickness (feet)	Lithologic Character	Water-Bearing Properties	Minerals	Paleontological
TERTIARY	Eocene	Wasatch Formation	395	Siltstone and medium-to coarse- grained, massive or cross-bedded sandstone, interbedded with carbonaceous shale, coal, and associated clinker.	Where saturated, sandstone beds probably could supply sufficient water for domestic and stock wells. <50gpm fair to good quality	Coal	Mammals, plants, including ferns
	Paleocene	*FORT UNION FORMATION*					Mammals, reptiles, amphibians, fish, plant fossils including leaves, seed pods, pollen, invertebrates, including bivalves, and gastropods
		Tongue River Member	650	Fine- to medium-grained, trough cross-bedded, plane-bedded, or massive sandstone. Interbedded with carbonaceous shale and siltstone, and 8 to 10 coal beds with associated clinker.	Important regional aquifers capable of producing large quantities of water.	Coal, clinker	
		Lebo Member	195 - 330	Smectitic or carbonaceous shale and silty shale with thin, interbedded sandstone and siltstone, and thin lenticular coal beds.	Leaky confining layer between the Tongue River and Tullock members.		
		Tullock Member	230-395	Fine- to medium-grained trough cross-bedded, plane bedded or massive sandstone. Interbedded with carbonaceous shale.	Important regional aquifers capable of producing large quantities of water.		
CRETACEOUS	Upper	Lance Formation	460-525	Fine-grained, cross-bedded, lenticular-bedded or massive sandstone, interbedded shale. In the lower part interbedded with coal, with some associated clinker. Laterally equivalent to the Hell Creek Fm.	Where saturated, sandstone beds probably could supply sufficient water for domestic and stock wells. <50gpm fair to good	Coal	Mammals, amphibians, birds, dinosaurs, other reptiles, pollen
		Fox Hills Sandstone	100	Siltstone and fine-grained cross-bedded or hummocky-bedded sandstone interbedded with shale.	Where saturated, sandstone beds probably could supply sufficient water for domestic and stock wells.		Invertebrates, including ammonites
		Bearpaw Shale	0-150	Fissile shale interbedded with thin, siltstone and fine-grained sandstone.	Relatively impermeable. Weathered part may contain some water, but probably the quantity would be small and the water highly mineralized.	Bentonite	Dinosaurs, invertebrates, including ammonites
		JUDITH RIVER FORMATION			Water bearing, <50gpm, poor to fair quality		Mammals, dinosaurs, other reptiles, birds, amphibians, fish, invertebrates including bivalves
		Upper Member	200-445	Sandy shale and shale interbedded with some thin sandstone beds.	Nearly impermeable. Would yield little to no water to wells.		
		Parkman Sandstone Member	255	Fine- to medium- grained cross-bedded sandstone interbedded with silty shale.	Lodge Grass obtains its municipal supply from a well that taps the Parkman. Wells that tap the basal sandstone yield adequate supplies of water; but to the north, where mudstone is present, yields are smaller and the water is more mineralized.	Oil and gas	
		Claggett Shale	395	Fissile or bentonic shale.	Small supplies of mineralized water can be obtained from the weathered shale. Some interbedded sandstone beds produce water. <50gpm, poor to fair quality	Bentonite	Invertebrates, including ammonites
		Gammon Formation	325-855	Calcareous siltstone interbedded with calcareous shale. Contains several fine grained sandstone beds and ferruginous concretions.	Relatively impermeable. Water probably highly mineralized.		
		Niobrara Shale	410-700	Fissile shale with abundant thin bentonite beds and concretions.	Nearly impermeable. Would yield little to no water to wells.		
		Carlile Shale	280	Fissile shale with sandy shale and bentonite beds at the base.	Nearly impermeable. Would yield little to no water to wells.	Bentonite	
		Greenhorn Formation	115	Calcareous, fossiliferous shale with bentonitic shale beds.	Nearly impermeable. Would yield little to no water to wells.	Bentonite	
		Belle Fourche Shale	395	Fissile shale and sandy shale with ferruginous concretions and bentonite beds.	Nearly impermeable. Would yield little to no water to wells.	Bentonite, oil and gas	
		Mowry Shale	605-705	Siliceous, very-fine to fine- grained sandstone and siltstone interbedded with fissile shale and bentonite beds including the Clay Spur bentonite.	Possibly would yield small amounts of mineralized water.	Bentonite	Fish
	Lower	Thurmopolis Shale and Fall River Sandstone, Undivided	605-705	Thurmopolis Shale: fissile shale in the upper part with fissile shale interbeds and laminae of argillaceous sandstone in lower part. Thin bentonite beds bentonite and ferruginous concretions. Fall River Sandstone: sandstone interbedded with shale.	Nearly impermeable. Would yield little to no water to wells.		
		Kootenai Formation	195-245	Bentonic mudstone interbedded with lenticular fine- to coarse- grained sandstone. Thin zones of nodular limestone in the upper part. Locally contains dinosaur remains. Greybull Sandstone Member locally present at top is a tick, lenticular, fine-grained sandstone. The Pryor Conglomerate Member at the base is 20 to 60 feet thick.	Yields small quantities of water to wells tapping the more permeable beds.		

Table 9 A
Geologic Section of theReservation

Generalized Geologic Section of the Crow Reservation

References: Vuke et al. 2000(a); Vuke et al. 2000(b); BIA 1973

System	Series	Formation	Thickness (feet)	Lithologic Character	Water-Bearing Properties	Minerals	Paleontological
JURASSIC	Upper	Morrison Formation	295-345	Variegated mudstone and very-fine to fine-grained quartzose, calcareous, cross bedded sandstone.	Water bearing, <50gpm, poor to fair quality		Dinosaurs
		ELLIS GROUP					
		Swift Formation	115	Fine- to coarse- grained, plane-bedded or cross-bedded, glauconitic, fossiliferous sandstone or very sandy limestone coquina at the top. Claystone interbedded with silty to sandy claystone in the lower part. Interbedded glauconitic, fossiliferous sandstone.	Water bearing, <50gpm, poor to fair quality		Pelecypods and belemnites
	Middle	Rierdon Formation	180	Limestone, sandy oolitic limestone, and fine-grained calcareous sandstone, with calcareous shale.	Probably not water bearing.		Oyster shells
		Piper Formation	131	Claystone with interbedded siltstone in the upper part. Contains dolomitic limestone interbedded with claystone and gypsum. Claystone and gypsum in middle part. Claystone and lenses of gypsum interbedded with some claystone, siltstone, and limestone in lower part.	Relatively impermeable. Water probably too mineralized for general use.	Gypsum	
TRIASSIC	Lower	Chugwater Formation and Goose Egg Formation undivided.	492	Chugwater Formation: Thin-bedded, locally cross-bedded, calcareous or gypsiferous, fine-grained and very fine-grained sandstone and siltstone with limestone. Goose Egg Formation: finely crystalline gypsum interbedded with fine-grained sandstone and siltstone.	Relatively impermeable.	Gypsum	
PENNSYLVANIAN		Tensleep Formation	98	Very fine -grained to medium-grained, cross-bedded sandstone with some thin limestone beds, nodular chert, dolomite, or silty shale.	Yields moderate to large supplies of water to wells that tap thick sections of the formation. Some flowing wells in the Soap Creek area have yielded more than 500 gpm with several hundred feet of head. Fair to good quality	Oil and gas	
	Lower	Amsden Formation	262	Shale, siltstone, and sandstone, interbedded with limestone and dolomite.	Large yields of water reportedly are obtained where rocks are brecciated or limestone is cavernous. 50-450gpm, fair to good quality	Vanadium/ Uranium	
MISSISSIPPIAN	Upper						
	Middle	Madison Group, undivided	656	Thick bedded to massive, fossiliferous, micrictic to coarse-grained limestone and dolomitic limestone. Contains solution breccia and karst surface with sink holes.	Formation contains numerous caverns, open joints, and fissures, and is the most prolific water-bearing formation. However, because the water is highly mineralized and the aquifer lies at such great depth, the Madison is not considered as an economical source of supply. 50-450gpm, good quality	Vanadium/ Uranium and limestone, oil and gas	Mainly crinoids, brachiopods, corals, and stromatolites
DEVONIAN	Upper	Three Forks Formation and Jefferson Formation	198	Three Forks Formation: Thin to medium bedded, silty to shaley limestone and dolomite interbedded with shale, siltstone, and sandstone. Jefferson Formation: dolomitic limestone.	Probably would yield considerable water to wells especially where brecciated. <50gpm, good quality		
ORDOVICIAN	Middle	Bighorn Dolomite	394-492	Micritic dolomite and dolomitic limestone.	Formation contains numerous caverns, open joints, and fissures, and probably would yield considerable water to wells. However, because the water is highly mineralized and the aquifer lies at such great depth, the Madison is not considered as an economical source of supply.	Oil and gas	
CAMBRIAN	Middle	Sedimentary rocks, undivided	705 to 804	Thin-bedded, limestone interbedded with shale, and intraformational limestone flatpebble conglomerate in the upper part. Fissile, calcareous silty or sandy shale in lower part with a coarse-grained sandstone.	Possibly would yield small amount of water to wells.		
PRE-CAMBRIAN		Granitic gneiss and schist		Pale-to moderate red granitic gneiss, medium dark-gray, quartzofeldspathic gneiss, biotite-hornblend schist, quartzite, and aplite, with mafic dikes and quartz veins.	Potentially could produce water in areas of fractured rock.		

Table 9B
Geologic Section of the Reservation

Overlying the bedrock are the following Holocene deposits:

- Alluvium consisting of gravel, sand, silt, and clay deposited along active channels of rivers, streams, and tributaries.
- Landslide deposits consisting of rock and soil that moved down slope as discrete units through mass-wasting processes.
- Alluvial terrace deposits of gravel, sand, silt and clay underlying older river terrace surfaces.
- Clinker deposits of thermally metamorphosed shale, siltstone, and sandstone of the Fort Union Formation.

These formations have been mapped on the reservation by the Montana Bureau of Mines and Geology and are best described in publications by Vuke et al. (2000a) and Vuke et al. (2000b).

The coal on the reservation occurs primarily in the continental deposits of the Tongue River Member of the Fort Union Formation. However, coal seams also occur in the underlying Lebo Shale Member and in the Tullock Member, and at the base of the overlying Wasatch Formation. Jacob (1973) and Bryson and Bass (1973) found evidence of cyclic deposition in the Fort Union Formation. The basic cyclic unit consisted of gray claystone and siltstone at the base followed by coal, yellow siltstone and clayey sandstone, and calcareous sandstone.

The siltstone and claystone were deposited on flood plains, the coals in the back swamp areas, the yellow sandstone and siltstone as levee and crevasse-splay deposits, and some of the massive sandstone bodies were point-bar deposits. The interbedded and cyclic nature of these continental deposits makes it difficult to correlate coal beds across the basin. The coal seams are found at different stratigraphic horizons as well as in the same horizon a few miles away. Some coal seams carry the same bed name from mine to mine and others are replaced with local names.

The Statewide Draft Oil and Gas EIS (pp. 3-6 and 3-7) presents an accurate description of the coal bearing geologic formations that are present on the Crow Reservation. Site-specific studies would be required to accurately reflect the geologic conditions at any one site.

Oil and Gas

There are six fields that have produced oil and gas on or near the reservation: Soap Creek, Lodge Grass, Gray Blanket, Hardin, Toluka and Ash Creek (*see Figure 11*). These fields produce out of the Fort Union, Shannon, Tensleep, Amsden, and Madison formations. A total of 172 exploratory and production wells have been drilled on the reservation. Production has declined in recent years and no new wells have been proposed.

Coal

The coal beds of the Fort Union Formation are located in the Rosebud-Wolf Mountains on reservation and ceded acreage. Coal underlies approximately 376,397 acres of the reservation and 322,378 acres of ceded land. It is estimated that there is between 700-800 million tons or 17 billion short tons of coal on lands whose mineral rights are controlled by the Tribe both on the reservation and ceded land (RMR 1977.

Reservation coal is classified as subbituminous C rank, which implies a high moisture content with BTU values from 8,300 to 9,500 on a mineral free basis, and are non-coking. This type of coal is used today for the production of steam in electrical generating plants.

The coal is produced primarily from nine coal beds (RMR 1977; Matson and Blumer 1973):

1. Roland: Top of Tongue River Member; average thickness 9 feet; resources 0.3 billion short tons; ranges in calorific value from 7,021 to 9,114 BTU, the sulfur content is 0.2 to 0.7%, and ash content 3.8 to 9.7%.
2. Smith: Tongue River Member; average thickness 7 feet; resources 0.3 billion short tons; ranges in calorific value from 7,607 to 8,272 BTU, the sulfur content is 0.6 to 1.0%, and ash content 6.8 to 30.2%.
3. Anderson: Tongue River Member; average thickness 20 feet; resources 1.9 billion short tons; ranges in calorific value from 8,705 to 9,850 BTU, the sulfur content is 0.2 to 0.6%, and ash content 2.9 to 6.2%.
4. Dietz: Tongue River Member two coal beds; average thickness 35 feet; resources 5.6 billion short tons; ranges in calorific value from 6,019 to 9,373 BTU, the sulfur content is 0.3 to 0.4%, and ash content 2.9 to 6.3%.
5. Canyon: Tongue River Member; average thickness 20 feet; resources 3.7 billion short tons; ranges in calorific value from 8,446 to 9,113 BTU, the sulfur content is 0.2 to 0.3%, and ash content 3.2 to 10.7%.
6. Wall: Tongue River Member; average thickness 20 feet; resources 4.9 billion short tons; ranges in calorific value from 7,637 to 10,079 BTU, the sulfur content is 0.1 to 1.1%, and ash content 3.1 to 12.5%.
7. Rosebud: Tongue River Member; average thickness 10 feet; resources 0.1 billion short tons; ranges in calorific value from 7,810 to 9,090 BTU, the sulfur content is 0.5 to 1.1%, and ash content 8.1 to 12.6%.
8. McKay: Tongue River Member; average thickness 10 feet; resources 0.1 billion short tons.
9. Robison: Tongue River Member; average thickness 10 feet; resources 0.05 billion short tons.

Mineral Materials and Locatable Minerals

The Statewide Draft Oil and Gas EIS (p. 3-8 Mineral Materials; Locatable Minerals) presents an accurate description of the potential minerals on the Crow Reservation. Coal, oil and gas, and bentonite on the reservation have the highest potential for development. *Tables 9A and 9B* present the geologic section for the reservation and the potential mineral deposits by formation. Site-specific studies would be required to accurately reflect the geologic and economic conditions for each deposit.

Paleontological Resources

The Crow Reservation includes bedrock deposited during the Late Cretaceous to Early Tertiary time. These geologic formations were deposited in a broad, epicontinental seaway that extended through the western interior from the Arctic Ocean to the Gulf of Mexico during Late Cretaceous. The cyclic transgression and regression of the shallow seas and the final withdrawal during the Late Tertiary time resulted in a wide variety of environments of deposition. The depositional environments of marine and nonmarine sedimentation resulted in a rich fossil record

including dinosaurs, mammals, and other vertebrate and paleobotanical remains. The great abundance, diversity, and generally excellent fossil preservation in the region present significant scientific research opportunities.

Detailed paleontological field surveys have not been conducted within the reservation, thus the specific nature of the fossil record and locations within the reservation are unknown. *Tables 9A and 9B* are the geologic section for the reservation with reference to potential paleontological resources by formation. Site-specific studies would need to be conducted prior to bedrock disturbance.